Dr J. J. Woodward
with the Compliments
of W. S. S.

Sullivant (W. S.)

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Notes on Mr. Charles Stodder's Paper entitled "Nobert's Test-Plate and Modern Microscopes," published in the American Naturalist, April, 1868. By W. S. Sullivant.

Mr. Stodder's paper above cited is full of interest to the microscopist. In it is announced the resolution of lines on the Nobert Test-plate* which are as close together as the $\frac{1}{112,668}$ of an English inch, and much exceed in fineness those heretofore seen by other observers.

From Mr. Stodder's brief sketch of what had been previously done in the separation of lines under the microscope, it appears that Ross, De la Rue, and Sullivant and Wormley after extended and exhaustive experiments on the Nobert test-plate, failed to resolve lines closer together than about the $\frac{1}{85,000}$ of an inch. It appears also that Nobert himself has never been able, with the highest powers, to see lines on his own test-plates closer together than the $\frac{1}{84,400}$ of an inch.

On the other hand, the late Professor J. W. Bailey claimed to have seen lines the $\frac{1}{100,000}$ of an inch apart; and Messrs. Harrison and Sollitt claim to have measured striæ on the diatom *Amphipleura pellucida* having an interval of the $\frac{1}{120,000}$ to the $\frac{1}{130,000}$ of an inch, and gave it as their opinion that lines as close as the $\frac{1}{175,000}$ of an inch could, with proper

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* The plate used in the trials detailed by Mr. Stodder is one of nineteen bands, the first being ruled to the $\frac{1}{1066}$ of a Paris line or to the $\frac{1}{112400}$ of an English inch, each band increasing by 500 so that the 19th band is ruled to the $\frac{1}{100000}$ of a Paris line or to the $\frac{1}{112668}$ of an English inch.

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means, be resolved. The above is learned from Mr. Stodder's paper.

There is no reason to question the results, such is their close accordance, obtained by the observers first mentioned, but in reference to the claims made by Professor Bailey and Messrs. Harrison and Sollitt, it may be remarked that Professor Bailey, though one of the most accomplished physicists of his day, was, owing doubtless to defects in the apparatus used, quite inaccurate in some of his micrometrical measurements;* and with regard to the alleged measurements of the striæ of *Amphipleura pellucida* by Messrs. Harrison and Sollitt, it is sufficient to say that it is now the generally received opinion among microscopists familiar with that diatom, that no true striæ have yet been seen on its frustules.†

From the foregoing it is not an unwarrantable inference that anterior to the experiments reported in the paper under notice, no satisfactory evidence is on record that lines closer than about the $\frac{1}{85,000}$ of an inch, either on Nobert's test-plate or any other object, have been resolved. This being the limit reached by previous observers, the skill in manipulation and in the management of the illumination, &c., that

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* He assigned to *Pleurosigma Spencerii* a striation of $\frac{1}{120006}$ to $\frac{1}{200000}$ of an inch, the real striation being only about $\frac{1}{90000}$ of an inch. (This Journal, Jan., 1850). The striæ of *Grammatophora subtilissima* are given by him as $\frac{1}{120000}$ to $\frac{1}{200000}$ of an inch apart, instead of about $\frac{1}{75000}$, the true distance, (this Journal, Jan., 1851).

† Mr. Lobb *(Carpenter on the Microscope,* 3d ed., p. 198,*)* claims to resolve *Amphipleura pellucida.* Professor H. L. Smith, of Gambier, Ohio, whose valuable additions to microscopical apparatus are well known, has given much attention to this diatom; he recently witnessed Mr. Lobb's alleged resolution of its frustule, and considers the lines exhibited as spectral or spurious, and such, he states, is the opinion of Mr. Wenham.

brings to view, so distinctly and palpably, lines ruled to the $\frac{1}{112,668}$ of an inch that they have actually been counted and measured and found to correspond with the registration on the test-plate (p. 100), challenges the admiration of all interested in microscopy, and proves by the inexorable test of experiment, that the resolution of such lines is not incompatible with the physical properties of light, as has been asserted by Fraunhofer and other writers of authority on optics.

The grade of some of the objectives with which these resolutions were made is scarcely less remarkable than the resolutions themselves. Reliance was placed, not so much on those beautiful achievements in optical art, the $\frac{1}{25}$ and the $\frac{1}{50}$ lately sent out by Powell and Lealand, as on objectives of a medium grade, such as a $\frac{1}{6}$ *immersion* and a $\frac{1}{5}$ *dry* by Tolles. Mr. Stodder says "these trials show conclusively that it is not the great power of the objective that is important, for in many of the trials here reported, the lower powers have given the best results, but the skill of the opticians in making the instrument."

The objectives of Mr. Tolles unquestionably rank among the best, but it may be doubted if evidence exists, unless it be these trials reported by Mr. Stodder, of their superiority to those made by Spencer in this country, and by Powell and Lealand and others in England. Hence it is a fair inference that the failure of previous efforts on the highest bands of the Nobert test-plate is attributable to causes other than an incapacity in the objectives used.

Mr. Stodder would have done an acceptable service to those who may hereafter attempt such investigations, had he gone somewhat into detail as to the system of illumination, the auxiliary apparatus, &c., adopted by himself and other gentlemen whose experiments he reports.

Such success in carrying up the resolvability of lines so far beyond the point at which well-directed efforts, sustained by theory, had placed it, will doubtless attract other observers to this field of research, where, among other sources of deception, none will be found more prolific than the spurious or spectral lines always shown by the objective working with oblique light and under a strain; for it may well be supposed that any objective, especially one so low as a $\frac{1}{8}$th would be strained in the resolution of lines ruled to the $\frac{1}{112,668}$ of an inch.

It is well known to all familiar with this subject, that it is impossible to distinguish, by their mere visual appearance, the spurious from the true lines on the highest bands of the Nobert plate. No lines, therefore, should be entitled to full confidence as being the true lines, unless verified by the micrometer, that is, counted, measured, and found to correspond with the registration on the test-plate.*

Mr. Stodder remarks "it has been said that the resolution of lines to the eye, implies the ability to count them, but this, I think, is a fallacy," and illustrates his remark by the difficulty of counting the pickets on a fence, at a given distance. The difficulty in both cases could perhaps be surmounted to the extent necessary, by enlarging the visual angle under which the lines and pickets appear to the eye, viz: by adding to the amplification of the microscope, and shortening the distance to the fence.

Among the highest bands of the Nobert plate, owing to the want of perfect flatness of field inseparable from the best objectives, a portion only of the width can at one time be

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* It is here assumed that the lines are ruled on the test-plate as indicated by Nobert; no error having yet been found on any of his plates.

brought into exact focus. If that portion, however is measured and its lines resolved under a suitable amplification, the data are obtained for the solution of the problem in hand, namely, the determination of the distance apart of the lines thus separated.

In another extract from Mr. Stodder's paper he says "in counting lines of such exquisite fineness, either the micrometer or the stage must be moved, and it is next to impossible to construct apparatus that can be moved at once $\frac{1}{100,000}$ of an inch and no more." This remark, coupled with the one above cited in which the supposed ability to count lines resolved to the eye is deemed a fallacy, suggests the inquiry, how was it satisfactorily ascertained that the *true* lines on the 19th band, ($\frac{1}{112,668}$) were seen (page 99) with a $\frac{1}{6}$ objective and under an amplification of 550 diameters?

Besides the low grade of the objective, a noteworthy feature in this performance, is the low amplification employed. Heretofore it has been found no easy task to confirm by count and measurement, lines $\frac{1}{85,000}$ of an inch apart, resolved by high-grade objectives, under an amplification of 6,000 diameters.

Mr. Stodder very correctly remarks that an exact and controlable motion in the micrometer or the stage for the purpose of counting the lines of the highest bands, is next to impossible. But in the mere counting of lines, amplification is the important requisite, not the micrometer, the office of which is simply to measure that portion of the width of a band in which the lines can be counted. Motion in the meas uring apparatus—the cobweb-micrometer, for instance—is required for the purpose mainly of setting the spider-lines so as to embrace accurately, and thus measure the portion of the band above mentioned, not for the purpose of measuring

off, line by line, one at a time, the Nobert lines, as Mr. Stodder seems to require: this, indeed, as before said, would be next to impossible.

But there are other methods of measurement, and it may be safely asserted that whatever lines the objective can resolve, amplification with illumination for counting them, and apparatus for measuring the space in which they are counted, are all within the reach of the microscopist.

Mr. Stodder's views on the micrometry of the Nobert lines, are certainly untenable. He invests the subject with insurmountable difficulties, and thus seems to ignore the only certain and reliable means of determining the nature, whether real or spectral, of any lines that may be seen on the high Nobert bands.

His paper, nevertheless, will form an interesting part of the literature of a subject that has long attracted much attention, namely, the limit of the resolvability of lines under the microscope. The experiments recorded by Mr. Stodder go far toward determining this limit. They show that there was an error in fixing it among lines about the $\frac{1}{85,000}$ of an inch apart. They also show that lines as close as the $\frac{1}{112,888}$ of an inch can be separated. These are the finest lines ever yet ruled on any test-plate. How much narrower an interval lines may have and still be resolved, cannot probably be determined with numerical precision, until the ingenuity of Nobert adds finer ruled bands to his test-plates.

In the meantime, microscopists will doubtless find "pleasant divertisement" in resolving with their $\frac{1}{5}$ths and $\frac{1}{6}$ths, the lines of the four or five highest bands of the present test-plate; and they would do well in dealing with even these bands to bear in mind that "no other sense approaches in power of self-deception to that of sight; and that, especially when the eye is strained by an eager observer, and the imag-

ination, perhaps, plays under the pressure of a theory, it is quite possible, after a little, to see almost anything that is expected."

NOTE.—Since the above was in type the writer has been kindly presented by Dr. J. J. Woodward, of the U. S. Medical Department at Washington, with a series of beautiful photographs, recently made by his assistant, Dr. E. Curtis, of all the bands of Nobert's 19-band test-plate. The first 15 bands are sharply and clearly resolved into their true lines; the 15th band, however, (which is ruled to the $\frac{1}{90000}$ of an English inch) requiring a hand-glass, magnifying four or five diameters, to show its lines distinctly.

The resolving and photographing such extraordinary fine lines rank first among any performances of the kind on record, and attest the remarkable skill of Dr. Curtis, who has accomplished both so successfully.

The objective used was a $\frac{1}{25}$ inch made by Powell and Lealand; amplification 1,000 to 2,000 diameters. The photographs of the 16th, 17th, 18th and 19th bands gave, as Dr. Woodward remarks, only false or spectral lines.